

SPOOL-TYPE HYDRAULIC DIRECTIONAL CONTROL VALVE HAVING REDUCED CAVITATION

Field of the Invention

[0001] The present invention is directed to a spool-type hydraulic directional control valve having improvements to reduce cavitation when the spool is in the float position

Background of the Invention

[0002] Hydraulic circuits are well known and utilized in a wide variety of machines to articulate linkages and turn motors. A typical hydraulic circuit comprises a hydraulic pump, a spool-type control valve, a double acting hydraulic cylinder, and a hydraulic fluid reservoir. The hydraulic pump draws hydraulic fluid from the reservoir and supplies the fluid to the control valve. The control valve manages the flow of hydraulic fluid from the hydraulic pump to the hydraulic cylinder, and between the hydraulic cylinder and the hydraulic fluid reservoir.

[0003] When hydraulic fluid is allowed to flow freely between the hydraulic cylinder and the hydraulic fluid reservoir, the hydraulic cylinder is able to move, or float, in response to external forces acting on it. A float condition may be used in certain situations to conserve energy when lowering a load, exploiting the weight of the linkage to move the hydraulic cylinder, rather than consuming energy to pump hydraulic fluid. During this process, the hydraulic cylinder may be caused to move so rapidly that hydraulic fluid in the hydraulic cylinder cavitates. When this occurs, the rate of hydraulic cylinder movement may become erratic. The resulting erratic movement of load which the hydraulic cylinder supports is undesirable.

[0004] A more complete description of the prior art hydraulic circuit illustrated in Figures 1 - 4 is presented in the Detailed Description section of this application.

Summary of the Invention

[0005] The present invention improves upon a typical hydraulic circuit to reduce the occurrence of cavitation during the float condition. More specifically, the present invention improves upon the valve spool of a typical spool-type control valve.

[0006] In a first embodiment of the present invention, the flow area of a first passageway on the valve spool is appropriately sized to reduce the flow of hydraulic

fluid from the head end of the hydraulic cylinder to the hydraulic fluid reservoir, such that a sufficient proportion of that hydraulic fluid instead flows internally through control valve and back to the rod end of the hydraulic cylinder to reduce cavitation when the valve spool is in the "float" position.

[0007] In a second embodiment of the present invention, a second passageway on the valve spool is removed, eliminating the hydraulic fluid flow path from the hydraulic fluid reservoir to the rod end of the hydraulic cylinder when the valve spool is in the "float" position. Additionally, the flow area of the first passageway on the valve spool is appropriately sized to reduce the flow hydraulic fluid flow from the head end of the hydraulic cylinder to the hydraulic fluid reservoir, such that a sufficient proportion of that hydraulic fluid instead flows internally through control valve and back to the rod end of the hydraulic cylinder with minimal cavitation when the valve spool is in the "float" position.

Brief Description of the Drawings

[0008] Figure 1 is a schematic representation of a prior art hydraulic circuit with a double-acting hydraulic cylinder and a spool-type hydraulic control valve typical of the prior art. The circuit is shown in "neutral" condition wherein the hydraulic cylinder is held in a static position against an external load by the hydraulic circuit.

[0009] Figure 2 is the schematic representation of the circuit shown in Figure 1, the circuit shown during a "raise" function wherein the hydraulic cylinder is being extended against an external load by the hydraulic circuit.

[0010] Figure 3 is the schematic representation of the circuit shown in Figure 1, the circuit shown during a "lower" function wherein the hydraulic cylinder is being contracted against an external load by the hydraulic circuit.

[0011] Figure 4 is the schematic representation of the circuit shown in Figure 1, the circuit shown in "float" condition wherein the hydraulic cylinder is being compressed by an external load.

[0012] Figure 5 is a schematic representation of a hydraulic circuit of the first embodiment of the spool-type hydraulic control valve of the present invention. The circuit is shown in "float" condition wherein the hydraulic cylinder is being

compressed by an external load.

[0013] Figure 6 is a schematic representation of a hydraulic circuit of the second embodiment of the spool-type hydraulic control valve of the present invention. The circuit is shown in “float” condition wherein the hydraulic cylinder is being compressed by an external load.

Detailed Description

[0014] Hydraulic circuits are well known and utilized in a wide variety of machines to articulate linkages and turn motors. Figure 1 illustrates a typical hydraulic circuit 10 suitable for manipulating a linkage. The hydraulic circuit 10 comprises a hydraulic pump 12, a spool-type control valve 14, a double acting hydraulic cylinder 16, and a hydraulic fluid reservoir 18. The hydraulic pump 12 draws hydraulic fluid from the reservoir 18 and supplies the fluid to the control valve 14. The control valve 14 directs the flow of hydraulic fluid from the hydraulic pump 12 to the hydraulic cylinder 16, and between the hydraulic cylinder 16 and the hydraulic fluid reservoir 18.

[0015] The hydraulic cylinder 16 illustrated in Figure 1 comprises a cylinder body 20 and a cylinder rod 22. The cylinder body 20 has a rod end 24 with a rod end port 26, and a head end 28 with a head end port 30. The cylinder rod 22 variably extends from the rod end 24 of the cylinder body 20, and translates in response to the flow of hydraulic fluid between the control valve 14 and the hydraulic cylinder 16. For illustration purposes, the hydraulic cylinder 16 is represented in a configuration where a load L is lifted against gravity when the hydraulic cylinder 16 is extended.

[0016] When hydraulic fluid is supplied to the head end port 30, and hydraulic fluid is allowed to escape from the rod end port 26, the cylinder rod 22 extends outwardly from the cylinder body 20 until hydraulic flow is discontinued, or until the travel limit of cylinder rod 22 is reached. Conversely, when hydraulic fluid is supplied to the rod end port 26, and hydraulic fluid is allowed to escape from the head end port 30, the cylinder rod 22 contracts inward towards the cylinder body 20 until hydraulic flow is discontinued, or until the travel limit of cylinder rod is reached.

[0017] When hydraulic fluid flow is closed-off at both of the head end port 30 and the rod end port 26, the position of the cylinder rod 22 remains static relative to the

cylinder body 20. Alternatively, when hydraulic fluid is allowed to flow freely at both of the head end port 30 and the rod end port 26, the cylinder rod 22 is able to move, or float, relative to the cylinder body 20 in response to external forces acting on the hydraulic cylinder 16. A float condition is commonly used applications where it is desirable for a linkage manipulated by the hydraulic cylinder 16 to be allowed to float over terrain. Alternately, a float condition may be utilized to conserve energy when lowering a load L, exploiting the weight of the linkage to compress the cylinder rod 22 towards the cylinder body 20 rather than consuming energy to pump hydraulic fluid. Examples of such applications include loaders and farm implements.

[0018] The control valve 14 illustrated in Figure 1 comprises a valve body 40 and a valve spool 42. The valve body 40 has a supply port 44, a first work port 46, a second work port 48, and first return port 50, a second return port 52, and a supply passage 54. In the illustrated system, the supply port 44 is fluidly connected to the hydraulic pump 12, the first work port 46 is fluidly connected to the rod end port 26 of the hydraulic cylinder 16, and the second work port 48 is fluidly connected to the head end port 30 of the hydraulic cylinder 16. Both the first return port 50 and the second return port 52 are fluidly connected to the hydraulic fluid reservoir 18.

[0019] The valve spool 42 illustrated in Figure 1 comprises a rod with a plurality of flow passages that variably extends within the valve body 40. The position of valve spool 42 relative to the valve body 40 determines the flow of hydraulic fluid within the control valve 14. The position of the spool 42 may be controlled either manually by an operator, or automatically by a mechanical or electronic control system. When the valve spool 42 is the “neutral” position as shown in Figure 1, hydraulic fluid flow is closed-off at all valve ports. Hydraulic fluid flow is thereby closed-off at both of the head end port 30 and the rod end port 26, and the position of the cylinder rod 22 remains static relative to the cylinder body 20.

[0020] When the valve spool 42 is moved left from the “neutral” position to the “raise” position, as shown in Figure 2, a fifth passageway 60 on the valve spool 42 allows hydraulic fluid to flow from the hydraulic pump 12 to the supply passage 54, while simultaneously, a first passageway 62 on the valve spool 42 allows hydraulic fluid to flow from the supply passage 54 to the second work port 48, creating a flow

path for the hydraulic pump 12 to supply hydraulic fluid to the head end port 30 of the hydraulic cylinder 16. A third passageway 64 on the valve spool 42 allows hydraulic fluid to flow from the first work port 46 to the first return port 50, creating a flow path for hydraulic fluid to escape from the rod end port 26 of the hydraulic cylinder 16 and back to the hydraulic fluid reservoir 18. The cylinder rod 22 is thereby caused to extend outwardly from the cylinder body 20 until hydraulic flow is discontinued, or until the travel limit of cylinder rod 22 is reached.

[0021] Conversely, when the valve spool 42 is moved right from the “neutral” position to the “lower” position, as shown in Figure 3, a fourth passageway 66 on the valve spool 42 allows hydraulic fluid to flow from the hydraulic pump 12 to the supply passage 54, while simultaneously, the third passageway 64 on the valve spool 42 allows hydraulic fluid to flow from the supply passage 54 to the first work port 46, creating a flow path for the hydraulic pump 12 to supply hydraulic fluid to the rod end port 26 of the hydraulic cylinder 16. The first passageway 62 on the valve spool 42 allows hydraulic fluid to flow from the second work port 48 to the second return port 52, creating a flow path for hydraulic fluid to escape from the head end port 30 of the hydraulic cylinder 16 and back to the hydraulic fluid reservoir 18. The cylinder rod 22 is thereby caused to retract inwardly towards the cylinder body 20 until hydraulic flow is discontinued, or until the travel limit of cylinder rod 22 is reached.

[0022] When the valve spool 42 of the control valve 14 is moved further right from the “lower” position to the “float” position, as shown in Figure 4, flow from the hydraulic pump 12 is closed-off to the supply passage 54. A second passageway 68 on the valve spool 42 allows hydraulic fluid to flow between the first return port 50 and the first work port 46, creating a flow path for hydraulic fluid to flow between the hydraulic fluid reservoir 18 and the rod end port 26 of the hydraulic cylinder 16. The first passageway 62 on the valve spool 42 continues to allow hydraulic fluid to flow between the second work port 48 and the second return port 52, creating a flow path for hydraulic fluid to flow between the head end port 30 of the hydraulic cylinder 16 and the hydraulic fluid reservoir 18. Additionally, the third passageway 64 on the valve spool 42 allows hydraulic fluid to flow between the supply passage 54 and the first work port 46, while a sixth passageway 70 on the valve spool 42 allows

hydraulic fluid to flow between the supply passage 54 and the second work port 48, creating a flow path for hydraulic fluid between the head end port 30 and the rod end port 26 of the hydraulic cylinder 16. The cylinder rod 22 is thereby able to move, or float, relative to the cylinder body 20 in response to external forces acting on the hydraulic cylinder 16.

[0023] When the illustrated hydraulic circuit 10 is placed in float condition, and an external force such as a lifted load L acts to compress the cylinder rod 22 towards the cylinder body 20 of the hydraulic cylinder 16, hydraulic fluid is expelled from the head end port 30 and is drawn into the rod end port 26 by the displacement of the cylinder rod 22. During this process, the cylinder rod 22 may be caused to compress so rapidly that an insufficient flow of hydraulic fluid is able to be drawn into the rod end port 26. Under this condition, the hydraulic fluid being drawn into the rod end port 26 is said to cavitate. When this occurs, the rate of cylinder rod 22 compression may become erratic. The resulting erratic movement of the hydraulic cylinder 16, and the load L which it consequently supports, is undesirable.

[0024] The present invention improves upon the prior art hydraulic circuit 10 illustrated in Figures 1 - 4 to reduce the occurrence of cavitation during the float condition. More specifically, the present invention modifies the valve spool 42 of the control valve 14 illustrated above to improve the flow of hydraulic fluid between the head end port 30 and the rod end port 26 of the hydraulic cylinder 16 when the control valve 14 is in the float position.

[0025] Figure 5 illustrates a first embodiment of the present invention. In this embodiment, the flow area of the first passageway 62 on the valve spool 42 is appropriately sized to reduce hydraulic fluid flow from the head end port 30 of the hydraulic cylinder 16 to the hydraulic fluid reservoir 18, such that a sufficient proportion of the hydraulic fluid expelled from the head end port 30 flows through the supply passage 54 of the control valve 14 and back to the rod end port 26 to reduce cavitation when the valve spool 42 is in the "float" position. For example, the first passageway 62 may be sized such that the ratio of flow through the second return port 52 compared with the flow through the second work port 48 is approximately the ratio of the square of the rod cylinder 22 diameter to the square of the cylinder body

20 diameter.

[0026] Figure 6 illustrates a second embodiment of the present invention. In this embodiment, the second passageway 68 on the valve spool 42 is blocked-off, eliminating the flow path for hydraulic fluid to flow between the hydraulic fluid reservoir 18 and the rod end port 26 of the hydraulic cylinder 16 when the valve spool 42 is in the "float" position. Additionally, the flow area of first passageway 62 on the valve spool 42 is appropriately sized to reduce hydraulic fluid flow from the head end port 30 of the hydraulic cylinder 16 to the hydraulic fluid reservoir 18, such that a sufficient proportion of the hydraulic fluid expelled from the head end port 30 flows through the supply passage 54 of the control valve 14 and back to the rod end port 26 with minimal cavitation when the valve spool 42 is in the "float" position.

[0027] Having described the illustrated embodiment, it will become apparent that various modifications can be made without departing from the scope of the invention as defined in the accompanying claims.